US006469628B1

(12) **United States Patent**
Richards et al.

(10) **Patent No.: US 6,469,628 B1**
(45) **Date of Patent: Oct. 22, 2002**

(54) **SYSTEM AND METHOD FOR USING IMPULSE RADIO TECHNOLOGY IN THE FARMING FIELD**

(75) Inventors: **James L. Richards**, Fayetteville, TN (US); **Larry W. Fullerton**, Brownsboro, AL (US); **Donald A. Kelly**, Niceville, FL (US); **David C. Meigs**, Huntsville, AL (US); **Timothy T. Payment**, Huntsville, AL (US); **James S. Finn**, Huntsville, AL (US); **William J. Tucker**, Dallas, TX (US); **William D. Welch, Jr.**, Huntsville, AL (US)

(73) Assignee: **Time Domain Corporation**, Huntsville, AL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/710,075**

(22) Filed: **Nov. 10, 2000**

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/456,409, filed on Dec. 8, 1999, now Pat. No. 6,300,903, and a continuation-in-part of application No. 09/407,106, filed on Sep. 27, 1999, which is a continuation-in-part of application No. 09/045,929, filed on Mar. 23, 1998, now Pat. No. 6,133,876.

(51) **Int. Cl.**[7] **G08B 23/00**

(52) **U.S. Cl.** **340/573.3**; 340/573.4; 340/539

(58) **Field of Search** 340/539, 572.8, 340/572.9, 573.1, 573.3, 573.4, 573.7, 991

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,641,317 A		2/1987	Fullerton	375/130
4,743,906 A		5/1988	Fullerton	342/27
4,813,057 A		3/1989	Fullerton	375/259
4,979,186 A		12/1990	Fullerton	375/239
5,363,108 A		11/1994	Fullerton	342/27
5,467,271 A		11/1995	Abel et al.	702/5
5,485,161 A		1/1996	Vaughn	342/357.13
5,526,357 A	*	6/1996	Jandrell	340/991
5,677,927 A	*	10/1997	Fullerton et al.	375/200
5,687,169 A		11/1997	Fullerton	370/324
5,712,782 A		1/1998	Weigelt et al.	701/50
5,721,679 A		2/1998	Monson	701/207
5,740,038 A		4/1998	Hergert	700/284
5,791,294 A	*	8/1998	Manning	119/721
5,832,035 A		11/1998	Fullerton	375/149
5,884,198 A	*	3/1999	Kese et al.	455/575
5,911,669 A		6/1999	Stentz et al.	56/10.2 F
5,995,895 A		11/1999	Watt et al.	701/50
6,062,125 A	*	2/2000	Larrick, Jr. et al.	375/295
6,052,647 A		4/2000	Parkinson et al.	701/215
6,058,351 A		5/2000	McCauley	702/5
6,133,876 A	*	10/2000	Fullerton et al.	342/375
6,208,248 B1	*	3/2001	Ross	340/552

* cited by examiner

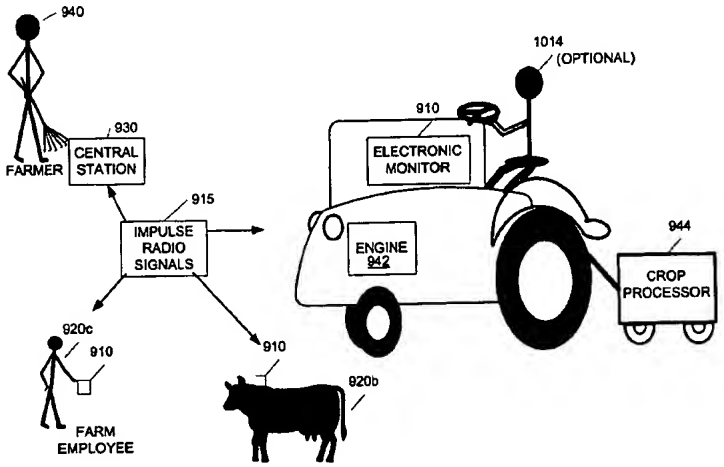
Primary Examiner—Van Trieu
(74) *Attorney, Agent, or Firm*—William J. Tucker

(57) **ABSTRACT**

A system, electronic monitor and method are provided that utilize impulse radio technology to enable a farmer to accurately track a position of an object (e.g., farm equipment, farm animal, farm employee) as the object moves around a farm and/or to enable a farmer to monitor a variety of parameters associated with the moving farm equipment. In addition, the system, electronic monitor and method can utilize impulse radio technology to help control either remotely or automatically one or more pieces of farm equipment.

48 Claims, 20 Drawing Sheets

Fullerton et al [5,677,927] + Manning [5,791,294]



Mixed Mode Tracking Architecture

For ease of reference, in FIGS. **20–25** the below legend applies.

Symbols and Definitions	
●	Receiver Radio (receive only)
X	Transmitter Radio (transmit only)
⊗	Transceiver Radio (receive and transmit)
R_i	Reference Radio (fixed location)
M_i	Mobile Radio (radio being tracked)
	Duplex Radio Link
	Simplex Radio Link
TOA, DTOA	Time of Arrival, Differenced TOA

Referring to FIG. **20**, there is illustrated a diagram of an impulse radio positioning network **2000** utilizing a mixed mode reference radio tracking architecture. This architecture defines a network of reference impulse radio units **R1–R6** comprised of any combination of transceivers (R_1, R_2, R_4, R_5), transmitters (R_3), and receivers (R_6). Electronic monitors (none shown) entering this mixed-mode reference network use whatever reference radios are appropriate to determine their positions.

Referring to FIG. **21**, there is a diagram of an impulse radio positioning network **2100** utilizing a mixed mode mobile apparatus tracking architecture. Herein, the electronic monitors **M1–M3** are mixed mode and reference impulse radio units **R1–R4** are likely time-synched. In this illustrative example, the electronic monitor **M1** is a transceiver, electronic monitor **M2** is a transmitter, and electronic monitor **M3** is a receiver. The reference impulse radio units **R1–R4** can interact with different types of electronic monitors **M1–M3** to help in the determination of the positions of the mobile apparatuses.

Antennae Architectures

Referring to FIG. **22**, there is illustrated a diagram of a steerable null antennae architecture capable of being used in an impulse radio positioning network. The aforementioned impulse radio positioning networks can implement and use steerable null antennae to help improve the impulse radio distance calculations. For instance, all of the reference impulse radio units **R1–R4** or some of them can utilize steerable null antenna designs to direct the impulse propagation; with one important advantage being the possibility of using fewer reference impulse radio units or improving range and power requirements. The electronic monitor **M1** can also incorporate and use a steerable null antenna.

Referring to FIG. **23**, there is illustrated a diagram of a specialized difference antennae architecture capable of being used in an impulse radio positioning network. The reference impulse radio units **R1–R4** of this architecture may use a difference antenna analogous to the phase difference antenna used in GPS carrier phase surveying. The reference impulse radio units **R1–R4** should be time synched and the electronic monitor **M1** should be able to transmit and receive.

Referring to FIG. **24**, there is illustrated a diagram of a specialized directional antennae architecture capable of being used in an impulse radio positioning network. As with the steerable null antennae design, the implementation of this architecture is often driven by design requirements. The reference impulse radio units **R1–R4** and the mobile apparatus Al can incorporate a directional antennae. In addition, the reference impulse radio units **R1–R4** are likely time-synched.

Referring to FIG. **25**, there is illustrated a diagram of an amplitude sensing architecture capable of being used in an impulse radio positioning network. Herein, the reference impulse radio units **R1–R4** are likely time-synched. Instead of the electronic monitor **M1** and reference impulse radio units **R1–R2** measuring range using TOA methods (round-trip pulse intervals), signal amplitude is used to determine range. Several implementations can be used such as measuring the "absolute" amplitude and using a pre-defined look up table that relates range to "amplitude" amplitude, or "relative" amplitude where pulse amplitudes from separate radios are differenced. Again, it should be noted that in this, as all architectures, the number of radios is for illustrative purposes only and more than one mobile impulse radio can be implemented in the present architecture.

From the foregoing, it can be readily appreciated by those skilled in the art that the present invention provides a system, electronic monitor and method that utilize impulse radio technology to enable a farmer to accurately track a position of an object (e.g., farm equipment, farm animal, farm employee) as the object moves around a farm and/or to enable a farmer to monitor a variety of parameters of the moving farm equipment. In addition, the system, electronic monitor and method can utilize impulse radio technology to help control either remotely or automatically one or more pieces of farm equipment.

Although various embodiments of the present invention have been illustrated in the accompanying Drawings and described in the foregoing Detailed Description, it should be understood that the invention is not limited to the embodiments disclosed, but is capable of numerous rearrangements, modifications and substitutions without departing from the spirit of the invention as set forth and defined by the following claims.

What is claimed is:

1. A method for tracking an object located on a farm, said method comprising the steps of:

attaching, to the object, an ultra wideband impulse radio unit;

determining a position of the object from the interaction between the ultra wideband impulse radio unit and at least two of a plurality of reference ultra wideband impulse radio units distributed at known locations throughout the farm;

receiving, at a central station, information relating to the position of the object;

displaying, at the central station, an overlay of the farm that indicates the position of the object; and

using the ultra wideband impulse radio unit and another ultra wideband impulse radio unit at the central station to establish two-way communications between a person at the central station and a person that is the object or is associated with the object, wherein the ultra wideband impulse radio unit is used to determine the position of the object and to establish the two-way communications between the person at the central station and the person that is the object or is associated with the object.

2. The method of claim **1**, wherein the object is a farm animal.

3. The method of claim **1**, wherein the object is a farm employee.

4. The method of claim **1**, wherein the object is a piece of farm equipment.

5. The method of claim 4, further comprising the step of using the determined position of the farm equipment to automatically operate the farm equipment.

6. The method of claim 5, further comprising the step of automatically steering the farm equipment along a crop line on the farm.

7. The method of claim 4, further comprising the step of using the determined position of the farm equipment to automatically control the farm equipment to distribute fertilizer.

8. The method of claim 4, further comprising the step of using the determined position of the farm equipment to automatically control the farm equipment to distribute seeds.

9. The method of claim 4, further comprising the step of using the determined position of the farm equipment to automatically control the farm equipment to distribute insecticide.

10. The method of claim 4, further comprising the step of using the determined position of the farm equipment to automatically control the farm equipment to irrigate the farm.

11. The method of claim 4, further comprising the step of coupling a controller to the ultra wideband impulse radio unit, wherein the controller interacts with a plurality of sensors that monitor at least one of the farm equipment.

12. A system for tracking an object located on a farm, said system comprising:

an ultra wideband impulse radio unit attached to the object;

a plurality of reference ultra wideband impulse radio units distributed at known locations throughout the farm at least two of which interact with the ultra wideband impulse radio unit to enable the determination of the position of the object;

a central station capable of receiving information relating to the position of the object;

said central station capable of displaying an overlay of the farm that indicates the position of the object; and

said central station including an ultra wideband impulse radio unit that interacts with the ultra wideband impulse radio unit attached to the object to establish two-way communications between a person at the central station and a person that is the object or is associated with the object, wherein the ultra wideband impulse radio unit attached to the object is used to determine the position of the object and to establish the two-way communications between the person at the central station and the person that is the object or is associated with the object.

13. The system of claim 12, wherein the object is a farm animal.

14. The system of claim 12, wherein the object is a farm employee.

15. The system of claim 14, wherein the object is a piece of farm equipment.

16. The system of claim 15, wherein said central station knowing the position of the farm equipment is further capable of automatically operating the farm equipment.

17. The system of claim 16, wherein said central station is further capable of automatically steering the farm equipment along a crop line on the farm.

18. The system of claim 15, wherein said central station knowing the position of the farm equipment is further capable of automatically controlling the farm equipment to distribute fertilizer.

19. The system of claim 15, wherein said central station knowing the position of the farm equipment is further capable of automatically controlling the farm equipment to distribute seeds.

20. The system of claim 15, wherein said central station knowing the position of the farm equipment is further capable of automatically controlling the farm equipment to distribute insecticide.

21. The system of claim 15, wherein said central station knowing the position of the farm equipment is further capable of automatically controlling the farm equipment to irrigate the farm.

22. The system of claim 15, further comprising a controller, coupled to the ultra wideband impulse radio unit, capable of interacting with a plurality of sensors that monitor at least one parameter of the farm equipment.

23. An electronic monitor comprising:

an ultra wideband impulse radio unit, attached to an object, capable of transmitting an impulse radio signal containing information to a central station that enables a person to track a position of the object moving on a farm, where the position of the object is determined from the interaction between the ultra wideband impulse radio unit and at least two of a plurality of reference ultra wideband impulse radio units distributed at known locations throughout the farm; and

said ultra wideband impulse radio unit is further capable of interacting with an ultra wideband impulse radio unit at the central station to establish two-way communications between a person at the central station and a person that is the object or is associated with the object, wherein the ultra wideband impulse radio unit attached to the object is used to determine the position of the object and to establish the two-way communications between the person at the central station and the person that is the object or is associated with the object.

24. The electronic monitor of claim 23, wherein the object is a farm employee.

25. The electronic monitor of claim 23, wherein the object is a farm animal.

26. The electronic monitor of claim 23, wherein the object is a piece of farm equipment.

27. The electronic monitor of claim 26, further comprising a controller, coupled to the ultra wideband impulse radio unit, capable of interacting with a plurality of sensors that monitor at least one parameter of the farm equipment.

28. The electronic monitor of claim 26, further comprising a display capable of displaying an overlay of the farm that indicates the position of the moving farm equipment and the at least one monitored parameter.

29. A method for tracking and monitoring a piece of farm equipment located on a farm, said method comprising the steps of:

attaching, to the farm equipment, an ultra wideband impulse radio unit;

receiving, at a central station, information from the ultra wideband impulse radio unit relating to the farm equipment;

displaying, at the central station, at least a portion of the information relating to the farm equipment;

determining a current position of the farm equipment by enabling the ultra wideband impulse radio unit to interact with a plurality of reference ultra wideband impulse radio units that are distributed at known locations around the farm by performing the following steps:

synchronizing the reference ultra wideband impulse radio units;

synchronizing the ultra wideband impulse radio unit to the synchronized reference ultra wideband impulse radio units;

collecting and time-tagging range measurements between the ultra wideband impulse radio unit and at least two of the reference ultra wideband impulse radio units; and

calculating the position of the farm equipment carrying the electronic monitor containing the ultra wideband impulse radio unit using the collected and time-tagged range measurements;

displaying, at the central station, the current position of the farm equipment; and

using the ultra wideband impulse radio unit and another ultra wideband impulse radio unit at the central station to establish two-way communications between a person at the central station and a person operating the farm equipment, wherein the ultra wideband impulse radio unit is used to determine the position of the farm equipment and to establish the two-way communications between the person at the central station and the person operating the farm equipment.

30. The method of claim **29**, wherein the information relating to the farm equipment includes at least one monitored parameter.

31. The method of claim **30**, wherein said step of displaying further includes indicating an alarm whenever one of the at least one monitored parameters exceeds a predetermined threshold.

32. The method of claim **29**, further comprising the step of using the determined position of the farm equipment to automatically control the farm equipment in accordance with an agronomic plan.

33. The method of claim **29**, further comprising the step of monitoring soil conditions.

34. The method of claim **29**, further comprising the step of monitoring crop conditions.

35. A system comprising:

an electronic monitor, attached to a piece of farm equipment, including an ultra wideband impulse radio unit capable of transmitting an impulse radio signal containing information relating to the farm equipment;

a central station capable of obtaining the information and further capable of displaying at least a portion of the information relating to the farm equipment;

a plurality of reference ultra wideband impulse radio units distributed at known locations throughout the farm at least two of which interact with the ultra wideband impulse radio unit to enable the determination of the position of the farm equipment by performing the following steps:

synchronizing the reference ultra wideband impulse radio units;

synchronizing the ultra wideband impulse radio unit to the synchronized reference ultra wideband impulse radio units;

collecting and time-tagging range measurements between the ultra wideband impulse radio unit and at least two of the reference ultra wideband impulse radio units; and

calculating the position of the farm equipment carrying the electronic monitor containing the ultra wideband impulse radio unit using the collected and time-tagged range measurements;

said central station capable of displaying an overlay of the farm that indicates the position of the farm equipment; and

said central station including an ultra wideband impulse radio unit that interacts with the ultra wideband impulse radio unit attached to the farm equipment to establish two-way communications between a person at the central station and a person operating the farm equipment, wherein the ultra wideband impulse radio unit is used to determine the position of the farm equipment and to establish the two-way communications between the person at the central station and the person operating the farm equipment.

36. The system of claim **35**, wherein the information relating to the farm equipment includes at least one monitored parameter.

37. The system of claim **36**, wherein said central station is further capable of indicating an alarm whenever one of the at least one monitored parameters exceeds a predetermined threshold.

38. The system of claim **35**, wherein said central station knowing a position of the farm equipment is further capable of automatically controlling the farm equipment in accordance with an agronomic plan.

39. The system of claim **35**, further comprising at least one sensor capable of monitoring soil conditions.

40. The system of claim **35**, further comprising at least one sensor capable of monitoring crop conditions.

41. An electronic monitor comprising:

a controller operable to monitor at least one parameter of a piece of farm equipment;

an ultra wideband impulse radio unit operable to interact with said controller such that a person can view at a central station the at least one monitored parameter;

said ultra wideband impulse radio unit is capable of interacting with at least two of a plurality of reference ultra wideband impulse radio units distributed at known locations throughout a farm to enable a determination of a position of the farm equipment by performing the following steps:

synchronizing the reference ultra wideband impulse radio units;

synchronizing the ultra wideband impulse radio unit to the synchronized reference ultra wideband impulse radio units;

collecting and time-tagging range measurements between the ultra wideband impulse radio unit and at least two of the reference ultra wideband impulse radio units; and

calculating the position of the farm equipment using the collected and time-tagged range measurements; and

said ultra wideband impulse radio unit is further capable of interacting with another ultra wideband impulse radio unit at the central station to establish two-way communications between a person at the central station and a person operating the farm equipment, wherein the ultra wideband impulse radio unit is used to determine the position of the object and to establish the two-way communications between the person at the central station and the person operating the farm equipment.

42. A method for managing a farm, said method comprising the steps of:

obtaining farm related information using ultra wideband impulse radio technology, wherein said step of obtaining farm related information further includes:

determining a current position of an object carrying an ultra wideband impulse radio unit by enabling the ultra wideband impulse radio unit to interact with a plurality of reference ultra wideband impulse radio units that are distributed at known locations around the farm; and

using the ultra wideband impulse radio unit and another ultra wideband impulse radio unit at a central station to establish two-way communications between a person at the central station and a person that is the object or is associated with the object, wherein the ultra wideband impulse radio unit is used to determine the position of the object and to establish the two-way communications between the person at the central station and the person that is the object or is associated with the object.

43. The method of claim **42**, wherein said step of obtaining the farm related information includes:

monitoring soil conditions and crop conditions on the farm.

44. The method of claim **42**, wherein the object is a farm animal.

45. The method of claim **42**, wherein the object is a farm employee.

46. The method of claim **42**, wherein the object is a piece of farm equipment.

47. The method of claim **42**, wherein said step of using the farm related information to increase the profitability of the farm includes:

automatically controlling the piece of farm equipment in accordance with the determined position and an agronomic plan.

48. The method of claim **47**, wherein the piece of farm equipment can be automatically controlled to distribute fertilizer, seeds, water or insecticides.

* * * * *